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16. Abstract

A brief survey is given of the use of wind power plants for rural electrification. The application of various alternative power supply systems involving wind power plants is examined, and the advantages and disadvantages of each alternative are presented.

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LINES OF DEVELOPMENT OF RURAL WIND POWER PLANTS

K. I. Shenfer and A. A. Ivanov[1]

The electrification of downstream areas, and above all the establishment of an extensive network of rural electric power stations of low and medium power, is an urgent task. Thus it is no accident that the location and utilization of inexpensive local raw material resources has led to the necessity of accelerated development of wind power plants of low and medium power utilizing the energy of wind, which is available in great abundance. /21*

The specific features of wind power are so obvious that a general description of them can be given despite the great diversity of individual areas from the standpoint of winds.

It has been established beyond dispute by a number of Soviet and foreign researchers that the wind speed increases with increasing distance from the Earth's surface. In the lower layer of the atmosphere, the so-called "ground eddy zone", air currents follow all the unevennesses of the topography and for this reason are characterized by great lack of uniformity of speed and direction and are broken down into individual eddies. The presence or absence of obstacles to the wind — hills, tall trees, structures, and so forth — heavily influences the nature of the phenomena. For example, anemograph recordings made at an average hourly wind speed of around 5-6 m/sec reveal wind speed fluctuations ranging from 0 to 10 m/sec, with individual gusts of 30 to 40 within one hour.

The wind conditions of the upper layers of air, the so-called "high--altitude zone", are characterized by greater uniformity and higher wind speeds than is the ground eddy zone. When fluctuations, although ones of relatively small amplitude, and short periods of calm are nevertheless possible even in these layers.

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[1]Institute of Power Engineering of the Academy of Sciences of the USSR.
*Numbers in the margin indicate pagination in the foreign text.

This brief survey of the characteristics of wind power suffice to demonstrate the inescapability of the conclusion that it is impossible to operate wind power plants in the ground eddy zone according to any firm schedule unless additional facilities are provided at the station which make up the brief power failures and supply power to consumers during periods of calm. It must not be forgotten, however, that isolated windmills mechanically connected to operating machinery nevertheless can provide more than 50% of all agricultural requirements, including the power required for such important operations as water supply, irrigation, cutting of tubers and straw, grinding of cottonseed cakes, milling, and so forth.

The same category of power loads which are not exacting from the standpoint of schedules includes heating devices, anticorrosive "charging" iron structures (long-distance oil pipelines), pump drives situated at some distance from a windmill, and so forth. However, an isolated wind power plant cannot be relayed on for such loads as lighting, the grid of small electric motors of machine tractor stations, auxiliary collective farm shops and the equipment of livestock and dairy farms, and so forth.

Thus the system of operation of an isolated wind power station must unquestionably be rejected in all cases when it is not possible to restrict operation to supply of "optional" consumers only, that is, ones who permit major or minor interruptions in power supply. In this context the question arises of the way in which the operation of a station can be supplemented so that power will be supplied in accordance with a firm schedule. There are several solutions to this problem, as is shown by the diagram in Figure 1.

The first possible alternative for conversion of the operation of a wind power station to a firm schedule is storage of wind power. The most inexpensive and dependable form of storage is represented by hydraulic storage. However, it possesses the basic disadvantage that reservoirs situated in the immediate vicinity of the windmill to be installed are required. Thus hydraulic storage is of limited applicability. Practical application has also been made to a certain extent of an innovation devised by Ufimtsev consisting in use of flywheels on generator shafts which are capable of making up brief power failures in the event of fluctuations in the wind.

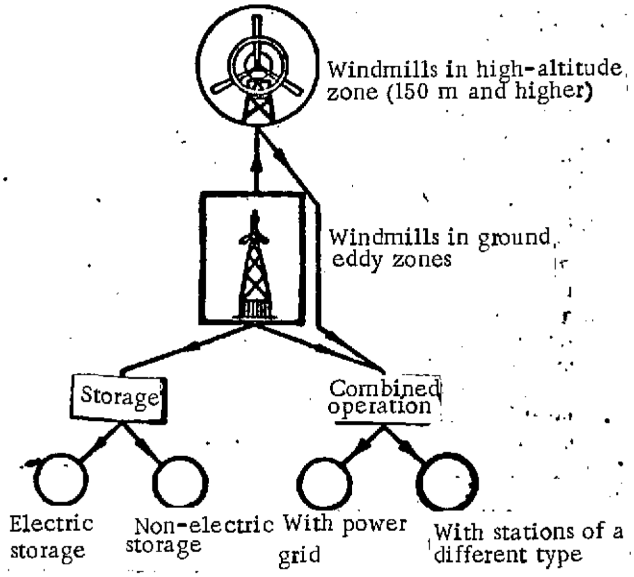

Figure 1. Alternatives for Conversion of Wind Power Stations to Operation on a Firm Schedule.

Electric storage, which is the simplest in principle, requires no special equipment whatever aside from a simple building and is entirely dependable in operation. However, the scarcity and costliness of materials for acid and alkaline batteries makes it necessary to avoid the use of batteries to to reduce their capacity. When a storage battery is selected which has a capacity adequate for operation on the "charge-discharge" cycle, and when it is not permissible for the plant to stand idle, the cost of the kilowatt-hour produced by the plant is found to be so high that such a system becomes uneconomical. Attention should be given to the system of a wind power plant having a storage battery operating as a positive booster. According to calculations made by G. A. Pechkoveskiy [1], it is possible in this case to /22
select a battery for 1/10 of the total voltage of the plant and have an automatic device permitting matched or opposed operation of the battery with a direct-current generator mounted on the windmill. In addition to making up for brief power failures in the event of wind fluctuations, such a battery can supply an emergency lighting network with full lighting current for a period of 2 days. The cost of 1 kilowatt-hour from the plant is much lower in this case than in operation of a battery selected for the "charge-discharge" cycle: at a wind speed v = 5 m/sec the cost of a kilowatt-hour is 20 kopecks and at v = 6 m/sec 15 kopecks.

Now let us consider the other possible alternatives shown in Figure 1 for conversion of a plant to firm schedule operation. As has already been pointed out, the wind conditions of a high-altitude zone are more favorable for windmill operation. In this instance the increase in the mean wind velocity is accompanied by decrease in fluctuation in the wind. But when windmills are built for operation in the high-altitude zone the cost of installing the high towers increases the capital outlays to such an extent that the low-power plant alternatives become entirely uneconomical. According to data available in the technical literature, foreign investigators, and in particular Honnef [2] and vanHeys [3] in Germany, have devised designs of high-power high-altitude wind power plants with an installed capacity of around 20,000 kVA, with inversion wind turbines of a diameter of around 100 m and a tower 150 to 300 m in height. The complexity of the electrical component of the system of such stations, the extremely great difficulties associated with completing the projects, and the necessity of maintaining a relatively small air gap in the extremely large inversion generator classify this problem as an interesting experiment but one of doubtful results. While we make no attempt to predict the subsequent development of the question of high-power high-altitude wind power plants, we nevertheless believe it is appropriate to remark that solution of such a problem is not as yet so urgent and timely in the Soviet Union that serious attention should be devoted to it or that the risk should be undertaken of building pilot installations.

The third alternative of conversion of operation of a wind power plant to a firm schedule appears to us to be the most advisable, that of combined operation of a wind power plant with a high-power grid or with stations of another type having commensurable power. The clustering of low and medium-power stations (including wind power stations) not requiring high-power transmission lines is of particularly great importance in the electrification of agricultural areas. For the sake of effective utilization of a windmill it is desirable to have a connection between the individual stations of the cluster (wind generating, water power, gas generating, locomobile stations, and so forth) flexible enough so that during periods of high winds the windmill will be loaded to full capacity and relieve the load on the other stations in the structure. Savings of fuel or water consumption can be accomplished with this solution. During a calm stations in the cluster not of the wind power type must increase their output in order to make up for the decrease in power yielded by the wind power plant. If the wind power plant plays the predominant role in the cluster in a system of 2 or more small power plants, conventional storage facilities or a small reserve may be provided to assure supplementary power. Storage and maintenance of a reserve assumed particularly great importance in the case of a cluster or wind power plants and small hydroelectric plants the output of which depends largely on natural conditions.

When a cluster is formed of small plants of different types a vital role must be played by automation and automatic regulation both of each individual station and of the cluster as a whole, especially when the cluster includes several wind or hydroelectric power plants. Modern hydraulic regulators for low-power hydraulic power plants are still very costly at present and production of such regulators is limited. However, in view of the fact that the number of revolutions of a microhydroelectric power plant varies approximately in the ratio of 1:2 with variation in the load, the generators must be regulated to keep the voltage constant, and intensive work should be done in this direction.

The authors have studied a system of parallel operations of a low-power AC-DC wind power plant and hydraulic power plant utilizing rectifiers [4].

A direct-current generator which can be regulated to keep the voltage constant by means of a non-linear resistance on change in the number of revolutions of the generator from 850 to 2,700 rpm is installed at the hydroelectric power plant [5]. The windmill, which has approximate aerodynamic regulation to keep the speed constant, rotates a synchronous generator which, as is shown in Figure 2, is connected to the direct-grid through an array of rectifiers. An undisputable advantage of the system in question is complete protection of the synchronous generator from the current of the hydroelectric power plant generator at low wind speeds, when the voltage of the rectified current is lower than the grid voltage. Rectifiers (copper oxide, selenium, magnesium--copper sulfite, and so forth) suppress the "reverse" current and thereby completely eliminate the need for installation of automatic devices providing for engagement and disengagement of the wind power plant as a function of wind speed.

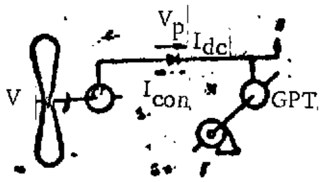

Figure 2. Diagram of Combined Operation of Direct-Current Wind and Hydroelectric Power Plants Through Rectifiers. V, windmill; I, hydraulic turbine; SG, synchronous generator; GPT, direct-current generator; Vp, rectifier; N, load.

Laboratory tests of the operation of the system have yielded good results both as regards distribution of loads between the two plants and the behavior of the generators on sudden disengagement of all or part of the load, and also as regards stability of the electric parameters of the grid supplied.

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